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Code 2A

(NASA TM X-51007)

OPERATIONAL PLANS AND PROCEDURES FOR MANNED SPACE FLIGHT

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~~To Be~~ Presented at

The Symp~~osium~~ of the Can~~adian~~ Aeron~~autics~~ and Space Inst~~itute~~

Astronautics Section

~~McGill University~~
Montreal, ~~Canada~~
Feb~~ruary~~ 28 - Mar~~ch~~ 1, 1963

NASA

OPERATIONAL PLANS AND PROCEDURES FOR MANNED SPACE FLIGHT

By John D. Hodge*

INTRODUCTION

The present paper is a discussion of many facets of the operations necessary to support the U. S. manned space flight programs. Operations means many things to many people. In this paper it is considered to be a two-fold function. The first part is planning which entails the total preparation for the mission before the fact. Table I is a list of some of the facets of this planning function. It is interesting to note that approximately 20,000 persons participate in a Mercury mission as direct operational support. These people come from industry, NASA, other civilian agencies, the Department of Defense, and other countries. The importance of this planning function cannot be overemphasized. The detail which this planning involves, such as scheduling, training, co-ordination, and preparation of procedures, contributes largely to the success of an operation. The second function is the carrying out of the actual operation. In this paper the various phases of the Mercury operation are discussed. Also an outline of the proposed Gemini and Apollo programs and the future of operations are presented. Although the planning phase is continuous, and essentially begins at the commencement of the program, the direct operation is assumed to begin when the spacecraft and the launch vehicle arrive at the launch site.

MERCURY

Since the Mercury spacecraft and the Atlas launch vehicle are well known, they are only described briefly. Figure 1 shows the Mercury spacecraft and its basic systems. The emergency escape tower separates the spacecraft from the launch vehicle should a malfunction occur before $2\frac{1}{2}$ minutes after lift-off. After this time, separation of the spacecraft from the launch vehicle is accomplished by firing the posigrade rockets which are located near the retrorockets.

The conical section (antenna housing) contains the drogue parachute, antennas, and horizon scanners.

The cylindrical section (recovery compartment) contains the main and reserve parachutes and the pitch and yaw thrusters.

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[illegible] and NASA [illegible] Only.

The afterbody contains all the systems necessary to support the astronaut, that is, the environmental control system, electrical system, communications system, automatic stabilization and control system, and all associated instrumentation.

The forebody contains the heat shield, the landing bag, and the major portion of the reaction control system.

The retropackage attached to the heat shield contains three posigrade rockets and three retrograde rockets and their associated igniters and wiring. The high-frequency antenna and a few special experiments are located in the retropackage.

Figure 2 shows the launch vehicles used for Mercury missions. The Little Joe vehicles were used for research and development tests, and the Redstone was used for early ballistic flights. The launch vehicle used for orbital flights is a modified Atlas D. The Mercury spacecraft is attached to the launch vehicle by means of a special adapter. The Atlas stands 67 feet 4 inches, but with the spacecraft it is 95 feet 4 inches in height. The Atlas has two stages with five engines: two booster engines, one sustainer engine, and two vernier engines. The two booster engines are jettisoned at staging, leaving the sustainer and the two verniers to place the spacecraft into orbit. The total thrust is 360,000 pounds, which is obtained by burning kerosene and liquid oxygen. The Atlas D has obtained a high degree of performance, and its reliability has been very satisfactory in the Mercury program.

The sequence of events during a normal Mercury mission are illustrated in figure 3. After lift-off, the Mercury-Atlas proceeds on a programed turn for about 2 minutes 10 seconds. At this time, the two booster engines are shut down and jettisoned. Twenty seconds later, the escape tower is jettisoned. The Atlas continues to accelerate, by using the sustainer engine, to an altitude of 87 nautical miles and a flight-path angle of 0°. At this time, the sustainer and vernier engines shut down. This sequence occurs about 427 nautical miles from Cape Canaveral, Fla. The apogee, or highest altitude, of the spacecraft is approximately 148 nautical miles. The orbital insertion conditions mentioned will place the spacecraft into an orbital inclination of $32\frac{1}{2}°$.

When SECO, or sustainer engine cutoff, occurs, the spacecraft separates from the Atlas and the astronaut yaws the spacecraft 180°, placing the heat shield toward the direction of the orbital motion. If the orbital insertion conditions are met, the spacecraft can continue for the planned number of orbits. So far, the United States has completed two three-orbit missions and one six-orbit mission and is presently planning a one-day mission in the near future.

The attitudes of the spacecraft may be controlled automatically by the automatic stabilization and control system, or by the astronaut using the fly-by-wire or manual proportional systems.

When it is desired to terminate the mission, the astronaut alines the spacecraft to a pitch down (-34°) attitude and normally selects the automatic system for retrofire. The retrorockets reduce the orbital velocity from 25,735 ft/sec to 25,300 ft/sec, a reduction of only 435 ft/sec, but sufficient to initiate the proper ballistic reentry which causes the spacecraft to land approximately 3,000 miles beyond the point of retrofire.

At an altitude of 10,000 feet the main parachute is deployed, and 12 seconds later the landing bag, which is a pneumatic device which attenuates the shock of impact on the water, is released.

OPERATIONS

In this section, the various phases of the operations for a Mercury-Atlas flight are described.

Preflight Operations

The preflight phase begins when the spacecraft is delivered to the launch site and ends at lift-off. This period varies from mission to mission, but the average is about four months. The spacecraft and launch vehicle are first checked out in detail, system by system, and independent of each other. At the conclusion of these detailed systems tests, a combined systems test is conducted, with the spacecraft using a launch-vehicle simulator and the launch vehicle using a spacecraft simulator. About 2 to 3 weeks before launch, again depending upon the mission, the vehicles are moved to the launch pad and mated.

Launch Pad Operations

The many tests involved in this phase of the operations are as follows:

1. Launch complex checkout
2. Interface inspection
3. Mechanical mating
4. Spacecraft systems test

5. Electrical interface and aborts

6. Flight acceptance composite tests

7. Flight configuration sequence and aborts

8. Launch simulation

9. Simulated flight

10. Spacecraft servicing

11. Precount, pyrotechnic hookup, and count

After the first seven tests in the list are completed, the simulated flight is the final test which completely checks all spacecraft systems during a simulated flight from lift-off to landing. The test also permits a check of the automatic launch-vehicle abort system.

Under some circumstances, a flight-readiness firing is performed during which all the Atlas engines are ignited for a period of 20 seconds to analyze the overall Mercury-Atlas systems configuration.

Precount, Pyrotechnic, and Launch Count

The countdown is performed in two parts. The first part, known as the precount, is primarily a check of the various spacecraft systems.

Following completion of this first part of the countdown, there is an approximate 15-hour hold for pyrotechnic check, electrical connection, and peroxide-system servicing and surveillance. During the launch count all systems are energized and final overall checks are made. The countdown begins again at T-390 minutes by installing and connecting the escape-rocket igniter. All systems are checked and the astronaut is inserted into the spacecraft at T-135 minutes. At T-90 minutes the hatch is bolted, and at T-35 minutes the launch vehicle is filled with liquid oxygen. At T-10 minutes the spacecraft changes from external to internal power and at T-3 minutes the launch vehicle also switches to internal power. At T-35 seconds the spacecraft umbilical is ejected, and at T-0 the Mercury-Atlas combination lifts off.

Flight Operations

The following paragraphs are a description of the operations which occur immediately prior to and during the actual flight.

About 2 weeks before the launch, the flight control teams are deployed to the many tracking stations around the world. They begin participating in network checkouts and simulations which assure equipment and personnel readiness. The simulations are of many types: those which check out the Mercury Control Center and astronaut for abort procedures; those which check out the reentry sites for retrofire decisions and procedures; and those which check out the entire World-wide Mercury Network for equipment, communications, and flight-control operating procedures.

The Mercury Network, shown in figure 4, consists of the Mercury Control Center at Cape Canaveral, Fla., the Communication and Computing Center at Goddard Space Flight Center, Greenbelt, Md., and other tracking stations around the world which are located along the spacecraft's orbital ground track. The Mercury Control Center is the command and control station which makes most of the decisions which affect the flight. The Communication and Computing Center is the central agency for relaying all teletype and voice communications from all the tracking stations and for doing most of the computing for spacecraft-trajectory purposes during all phases of flight.

The remaining tracking stations around the world are referred to as the "remote sites" and they provide monitoring capability needed for relaying telemetry, radar, and voice data back to the Mercury Control Center.

The recovery forces are also deployed at about the same time, and they participate in their individual and combined recovery exercises in a manner similar to that of the Mercury Network.

On the final day, all operational forces participate in the actual launch countdown which is fully coordinated and synchronized.

The in-flight phase begins at lift-off and continues through landing. The Operations Director, situated in the Mercury Control Center, is responsible for the overall operation. He is supported by a staff and organization as shown in figure 5. The mission is supervised, using a centralized control technique where all major decisions are made at the Mercury Control Center. This idealized situation, of course, is not always feasible and procedures are established to insure timely action in the event of contingencies if communications with the Mercury Control Center are broken. For the Mercury mission, by far the most critical time period is the powered-flight phase. During this period the dynamic conditions are changing continuously, and at all times actions in the event of malfunctions must be immediately available to assist the flight controllers and the astronaut in taking the proper corrective steps. A set of mission rules is prepared prior to the mission to cover

all recognizable situations. Of course, other situations which have not been recognized will occur from time to time, and the main purpose of the extensive simulation and training program is allow the flight controllers to make the correct decisions under these circumstances. Probably the single most critical function which is performed is the determination of the orbital parameters immediately after the cutoff. It is essential that the orbit capability of the vehicle be rapidly determined so that the decision to continue or to reenter immediately in an abort or contingency landing area can be made. Figure 6 is the plot which is used to assist in making this decision. It is derived by a computer and may use a number of tracking sources. A suitable orbit is obtained if the velocity ratio and the flight-path angle are within the lens-shaped area on the right-hand side.

During the orbital phase, there are several functions to be performed, although in general, decision making is not always as critical as it is during the powered-flight phase. Both the astronaut and the ground system continuously monitor the vehicle, its status, and the flight plan. Trends are established which determine whether or not a potential contingency exists. At all times the astronaut is informed of the correct retrofire time to achieve a landing in a contingency landing area. (The manner in which the various landing areas are established is discussed in a subsequent section of this paper.) It is important to remember the significant part that the astronaut plays in the successful completion of a mission. The spacecraft has many modes of operation and the astronaut is a systems manager. As the situation or flight plan dictates, he is able to select the best mode of operation and to control his consumables in the desired manner. Under many abnormal conditions, his presence enhances the possibility that the mission will continue to the successful accomplishment of all planned objectives. During this orbital period, the flight controllers at the remote sites act as the eyes and the ears of the Mercury Control Center, and after the spacecraft has passed over the station, they transmit summary reports to the Mercury Control Center. At the required time, preparations are made for the retrofire maneuver which may be controlled either manually or automatically. Firing of the retrorockets can be accomplished by the onboard clock, by the astronaut himself, or by ground command. The estimated landing position is determined either by radar tracking or by utilizing telemetry information obtained during the period of retrofire. The recovery forces are then alerted as to the estimated landing position. They are prepared to locate and retrieve the spacecraft and astronaut after landing.

Recovery Operations

The recovery operation is planned around the concept that there are several discrete areas along the ground track which are preferred landing areas. These areas are divided into several categories. First, the

launch site recovery area is selected to retrieve the astronaut if an abort were to occur either before lift-off or during the first few seconds of powered flight. During this period, most of the landings will occur on the land area around the launch site. The other areas are depicted in figure 7. Along the launch track, several areas are selected to cover aborts during the 5-minute period of powered flight. During this time, the landing area traverses the Atlantic Ocean to the African coast. By suitable selection of the time to fire the retro-rockets, it is possible to reduce the total number of landing areas as shown in figure 7. Next, planned landing areas are situated at the end of the mission, and there is at least one planned landing area along the ground track of each orbital pass. (See fig. 8.) Recovery forces are deployed in these areas to allow location and retrieval within 3 to 5 hours after landing. The remaining recovery areas are contingency landing areas which are located to give a landing capability in case of emergency as shown in figure 8. Because of the very low probability of landing in these areas, recovery forces are not usually predeployed but are on a standby basis. Location and pararescue assistance is available within 18 hours. The actual retrieval time will depend on the situation. The two functions of recovery are location and retrieval. Location is usually accomplished by aircraft equipped with direction-finding equipment. In addition, ground based high-frequency direction-finding facilities are used as well as a MILS network depending on sound waves initiated by a SOFAR bomb which is released from the spacecraft at landing. Retrieval is accomplished in the planned landing areas by the helicopters, destroyers, or carriers. In the contingency landing areas, location will be followed by a pararescue team dropping into the area of the spacecraft to render assistance to the astronaut as required and to insure that the spacecraft remains afloat.

GEMINI

As an intermediate step between Projects Mercury and Apollo, the objectives of Project Gemini are:

1. To provide long-duration manned flight experience (up to 14 days) by studying effects of weightlessness, determining physiological and psychological reactions to long-duration missions, and developing performance capabilities of the crew.

2. To provide early manned rendezvous capability by developing techniques, assessing pilot functions, developing propulsion guidance and control, developing pilot displays, and training pilots and providing them with rendezvous experience.

The Gemini spacecraft shown in figure 9 is a conical structure bearing a marked resemblance to its predecessor, Mercury. It consists basically of a reentry module and an adapter. The reentry module consists of a heat shield, crew and equipment section, reaction control system section, and the rendezvous and recovery section. The first section is pressurized to house the two astronauts seated in rocket catapult ejection seats in a side-by-side configuration with the command astronaut on the left and the second astronaut on the right. The astronauts face rearward and can visually observe the space environment through the observation windows provided in the ingress-egress hatches. The last two sections are unpressurized compartments. They contain tricycle, ski-type landing gear, the paraglider wing, and systems necessary to control the spacecraft attitude during orbital and reentry flight. External access doors are provided for equipment compartments which greatly reduce checkout time and component replacement.

The adapter consists of the launch-vehicle mating section, the equipment section, and the retrograde section. The launch-vehicle mating section is bolted to the launch vehicle, and a portion of this section remains with the launch vehicle when it separates from the spacecraft. The equipment section contains major components of the fuel cells and their reactant supply, the maneuvering propulsion system, the equipment cooling system, and the primary oxygen supply for the environmental control system. The retrograde section contains the retrograde rockets and some components of the equipment cooling system.

The vehicle used to launch the Gemini spacecraft is a modified Titan II, which used nitrogen tetroxide as an oxidizer and UDMH (unsymmetrical dimethyl hydrazine) as the hypergolic fuel. The Agena D vehicle, which will be launched by an Atlas launch vehicle, will be used as the target vehicle for Gemini rendezvous and docking. Both the Gemini-Titan and the Atlas-Agena configurations are shown in figure 10.

The Orbital Mission

The normal mission can be logically divided into six basic phases. They are prelaunch, launch, orbit, retrograde, reentry, and landing.

The prelaunch phase is essentially the same as that previously described for Mercury, with the exception that much of the Gemini checkout will be automatic. These automatic checkout procedures will reduce the time necessary for checkout at Cape Canaveral from the 4 months for the Mercury to $2\frac{1}{2}$ to 3 months for Gemini.

The launch phase covers the countdown, the astronauts' entry into the spacecraft, changeover from external to internal electrical power systems, lift-off, and the first and second stages of powered flight.

In the orbital phase, as in Mercury, the spacecraft turns 180° in yaw so that the astronauts face away from the direction of motion. Apart from any particular mission maneuvers, for the long-duration flights the spacecraft will stay in this orientation for the complete orbital duration. Thirty seconds before retrograde is planned, the equipment section of the adapter is jettisoned. The retrograde rockets are fired sequentially and the retrograde section of the adapter is jettisoned. The reentry phase of the mission includes the accurate positioning of the spacecraft to minimize heating, and by use of angle of attack and hence a moderate lift-to-drag ratio and the onboard computer, the astronauts may make flight-path corrections to assure touchdown within the desired area. When all guidance errors are corrected, the lift vector is canceled by putting the spacecraft into a slow 20°/sec roll. The landing phase begins when the astronaut initiates deployment of the drogue parachute. Subsequently, the drogue parachute is used to extract the paraglider. By controlling the paraglider in pitch and roll via the central hand controller, either astronaut can fly the spacecraft to a conventional landing site. The paraglider is jettisoned after touchdown.

Rendezvous

The rendezvous mission as shown in figure 11 is accomplished by placing the Agena target vehicle in orbit and then sometime later, placing the Gemini spacecraft in a similar orbit. Vehicle propulsion capability is used to bring the Gemini into a docked position with the Agena. The Atlas does not provide sufficient power to insert the Agena into orbit. Final insertion will be accomplished by the Agena itself; and when the desired orbital conditions are obtained, the Agena engine will be shut down, but ready for relighting at a later time.

After the Agena target is in orbit, the modified Mercury ground tracking stations will determine whether or not the Agena is operational and is in the proper orbit for rendezvous. There will be a period of time during which the Gemini might be launched and be in close proximity to the Agena. By relighting the Agena propulsive system and changing its orbit to conform more closely to the Gemini orbit, the window can be extended in excess of 4 hours. The Gemini will either be launched during this window or during a corresponding window at time intervals of about 24 hours.

The mission objective is to complete the rendezvous by using spacecraft propulsion only. However, the Agena propulsion is available if it is required. The Agena has an operation lifetime in orbit of

at least 5 days. However, present plans are to complete the rendezvous within 24 hours. Launch timing and midcourse corrections of the Titan II will be such that the Gemini spacecraft will be placed in close proximity to the Agena. The Gemini vehicle will be in an orbit with an altitude of 87 to 161 nautical miles. The astronauts will control the Gemini vehicle to approach the Agena in accordance with instructions from ground tracking stations.

As the Gemini approaches within 250 nautical miles of the Agena in orbit, the Gemini can be guided toward its target automatically by aid of an onboard radar and computer, or the astronaut may control the spacecraft manually. After using the radar system aboard the Gemini to close within about 20 miles of the Agena, the astronauts will be able to use the high intensity, flasing light aboard the Agena for optical tracking. At this time the two vehicles, although traveling at some 18,000 mph, will have a speed differential of only 1 to 2 mph. Final docking will be achieved by manual control of the Gemini by placing the nose of the Gemini into the docking collar of the Agena. There is a possibility that a television camera will be mounted on the Agena or in the Gemini so that the flight controllers can monitor the docking procedures.

During the latching part of the docking phase, when clamps inside the Agena collar grasp the Gemini nose cone and pull it into a latched position, the instrumentation wires will also be connected. The astronaut will then be able to observe the status of the Agena systems. Facilities aboard the Gemini spacecraft will enable the pilot to start the Agena propulsion system.

The Agena engine will have multirestart capability; thus, when the Gemini arrives in orbit, it will have another engine waiting there to supply power for orbital maneuvering. Here the engine can be used for adjusting the orbit, extending the apogee of the orbit, or for changing to another orbit.

With the ability to maneuver in space, the Gemini pilots might use the Agena to thrust the Gemini spacecraft into a different orbit for better choice of a landing site; they might control their direction for a specific landing location even though their craft were not going to pass over that region during that orbit.

There is thus available a flexible system with which to perform a variety of missions in achieving the desired objectives.

Because of the experience gained in Project Mercury, it is possible to reduce the number of network stations required to monitor the mission. The orbital missions will be directed from the Mercury Control Center with some slight modifications. For the rendezvous missions, a new Integrated Mission Control Center is under construction near Houston, Tex.

Recovery operations will remain essentially similar to those of Mercury. One variation which should be mentioned is that some recovery areas, particularly along the launch trajectory, will be enlarged, because of the variable launch azimuth of the Gemini launch vehicle. In addition, the Gemini spacecraft has a land landing capability utilizing the paraglider.

PROJECT APOLLO

The Apollo operations plan as shown in figure 12, is, like those of Mercury and Gemini, to be a step-by-step program of increasing complexity. The program will consist of three phases: first, long duration orbital flights; second, flights which approach the moon and possibly orbit the moon; and third, the lunar landing mission.

Figure 13 is a diagram of the Apollo spacecraft. It is composed of three basic sections: the command module, the service module, and the lunar excursion module. The command module houses the astronauts and contains all systems necessary for the astronauts to carry out their control functions during the mission. In addition, it contains consumables of sufficient quantity for a reentry maneuver, a sustained period prior to recovery, and an adequate reserve supply. The service module contains the major propulsion system, the majority of the power system, and all those additional systems necessary to complete the normal lunar mission. The lunar excursion module is a completely self-contained unit which is capable of separating from the command and service module, performing a maneuver to land on the moon, remaining on the moon for as much as a day, and performing a rendezvous maneuver with the command and service module at the completion of the lunar mission. The command module has a normal crew of three, two of which form the crew of the lunar excursion module for the lunar landing mission. The lunar excursion module has a capability of returning to the command and service module at any time during the lunar landing maneuver. From an operational point of view, there are several differences between the Apollo mission and the previous missions. First, there is a crew of three as compared with two for Gemini and one for Mercury. Second, the crew has a larger capability for onboard control than in previous missions. Essentially, the crew has the capability to complete a normal mission from lift-off to landing without the assistance of the ground systems. Of course, the major purpose of the ground system is to assist in the case of a normal mission and to provide the required emergency action in the event of malfunctions of either the spacecraft or the launch vehicle. Third, the Apollo vehicle has the capability for a relatively large velocity variation, and as a result the number of alternate missions and mission aborts that can be performed in the event of system malfunctions is extremely large.

The launch vehicles which are to be used for the Apollo manned space flights are the Saturn C-1, Saturn C-1B, and the Saturn C-5. The Saturn C-1 and Saturn C-5 are shown in figure 14. The C-1 is a two-stage vehicle. The first stage has eight engines which use liquid oxygen and RP-1 (a form of kerosene). The second stage is the S-IV which is a propelled by liquid hydrogen and oxygen. The C-1B is similar to the C-1 except that the second stage is restartable. The C-5 is a three-stage vehicle. The lower stage consists of five F-1 engines which use a combination of RP-1 and liquid oxygen. The second stage is the S-II which is a liquid hydrogen and oxygen stage, and the third stage is the S-IVB similar to that used as the second stage of the C-1B vehicle. All vehicles are inertially guided. The objective of the early orbital manned flights of the Apollo vehicle is primarily to prove the total system in the space environment for long durations comparable to those required for the lunar mission. Several missions are involved which will gradually build up the capability of the vehicle and progressively use all the required systems. The early vehicles will utilize a communications system having a range which is compatible with those of the present Mercury and proposed Gemini systems. For example, it will have a C-band tracking beacon, UHF telemetry system, UHF voice systems, and a UHF command system, all of which will operate at different frequencies. Eventually, the ground network will be modified to operate with the spacecraft at a single frequency in the S-band range. All information flowing between the spacecraft and the ground will be obtained by modulation of this single frequency. The operations plans for these orbital flights will be very similar in nature to those used for the Mercury and Gemini orbital flights. The preflight checkout will continue to become more automated, using essentially a computer controlled checkout system. Mission control will be exercised from the Integrater Mission Control Center. The Apollo program will then continue on to the lunar phase. This phase will consist of a series of circumlunar flights leading eventually to the lunar landing mission.

Figure 15 shows the basic sequence of events for the lunar landing mission. The launch will be conducted from Cape Canaveral, Fla. The variable launch technique will be used to provide, approximately, a 4-hour window during each day. In addition, the vehicle will first be put into earth orbit and will remain in orbit for a period of from one to four revolutions. This orbital period will be used to check out the total vehicle and to provide further flexibility in selecting the injection point for the translunar portion of the trajectory. At the required time, the S-IVB will be restarted and the vehicle will be accelerated to approximately 36,000 feet per second. Following injection, the S-IVB stage will be separated from the spacecraft and the lunar excursion module will be rotated to the forward end of the spacecraft. In this configuration such modifications to the trajectory as are required will be made during the translunar phase. When the vehicle

reaches the vicinity of the moon, a braking maneuver which places the spacecraft in orbit around the moon will be performed. Two members of the crew will transfer to the lunar excursion module which will then be separated from the command-service module combination. The two vehicles will then be placed in different, but equal period orbits. The orbit of the lunar landing module will result in a lunar landing, and the orbit of the command and service module will allow constant observation of the lunar excursion module during this critical landing maneuver. The landing will most probably take place during the period of earth shine; that is, with the sun behind the moon, and within a 10° band of the lunar equator. Sufficient time will be allowed on the moon to perform the required scientific experiments - probably a period of several hours. The launch countdown will then begin and a rendezvous maneuver will be performed using the propulsion system on the lunar excursion module. The crew and certain equipment will be transferred to the command and service module and the lunar excursion module will again be separated. An injection maneuver will then be performed and the vehicle will be placed into the transearth trajectory. This trajectory will be shaped so that it will give a free return to the required landing point on the earth. Modifications to this trajectory will be made as required by using the spacecraft propulsion system. The service module will be separated from the command module just prior to reentry into the earth's atmosphere, at approximately 36,000 feet per second. The command module has a lifting capability which is controlled by rolling the lift vector. Range variations of several thousand miles are possible, and this control capability will be utilized to land the vehicle at the required position on the earth. It is most likely that more than one planned landing area will be arranged to provide flexibility so that missions can be launched on most days of the month. In addition to the planned recovery areas, contingency areas will be set up similar to those in Mercury and Gemini, and present plans indicate that a high-frequency direction-finding location technique will be used for these areas.

POSSIBLE FUTURE PROGRAMS

Two possible future manned programs which are being investigated by the National Aeronautics and Space Administration are interesting to examine from the operational point of view. The orbiting earth laboratory which remains aloft for many months or even years provides an interesting operational logistics problem. Vehicles must be launched at regular intervals to replace consumables, to rotate the crews, and to change experiments if necessary. In addition, a continuous escape capability must be provided the crew in order that they may reenter safely to the earth should difficulties arise on the space station. Another interesting program is related to interplanetary flights. The major problem in these programs will probably be the design of the spacecraft

itself since missions of many months duration are probable and no logistic operation for resupply is possible.

CONCLUSIONS

In this paper, the operations which were necessary to support the Mercury program have been discussed. Also, plans which are being formulated for the Gemini and Apollo missions have been examined. Although it was not possible to describe these plans in detail, it is hoped that some insight into the operations plans and procedures required for manned space flight has been provided.

TABLE I. - OPERATIONS PLANNING

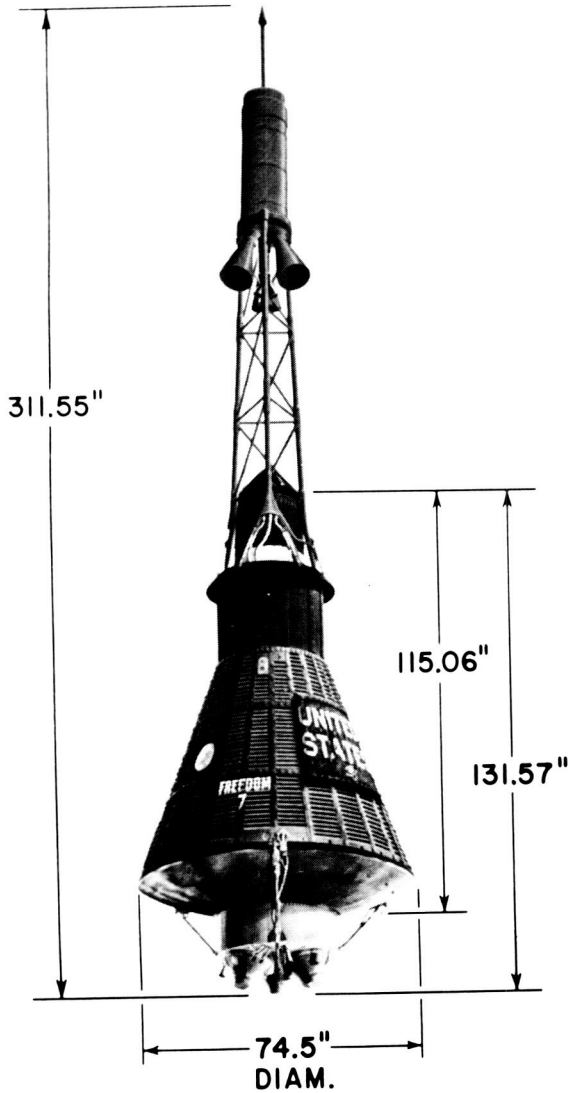
Mission planning
- Preflight planning
- Flight operations planning
- Recovery planning

Ground support planning
- Vehicle checkout facilities
- Network facilities
- Ground support equipment

Training
- Flight crew
- Ground support personnel

Mission preparation
- Scheduling
- Documentation
- Operations coordination

PROJECT MERCURY
MANNED ORBITAL SPACECRAFT



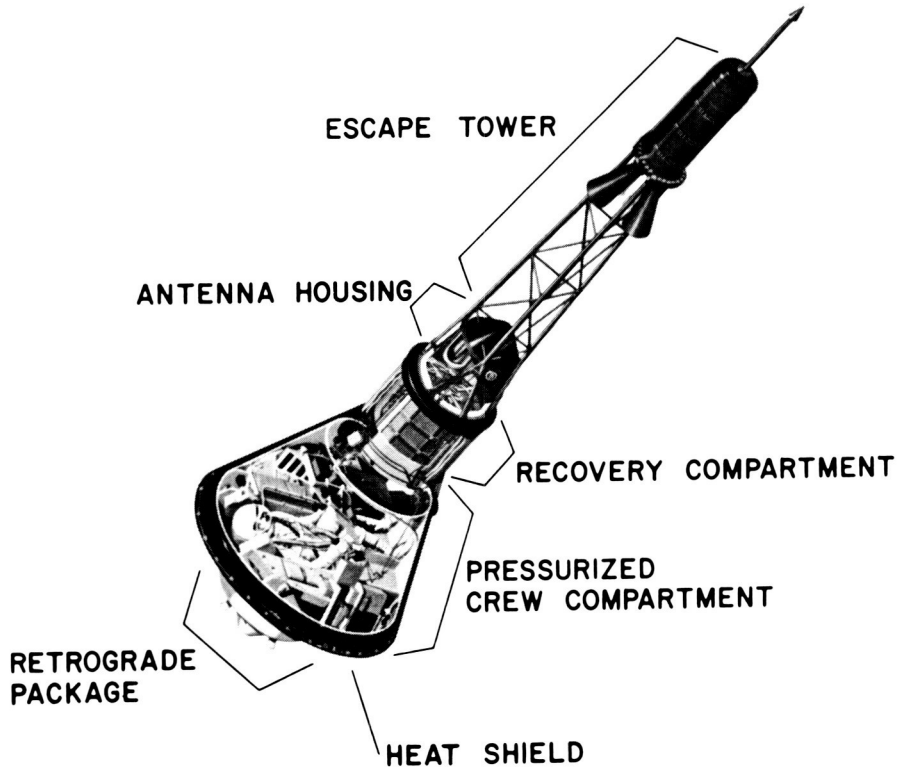
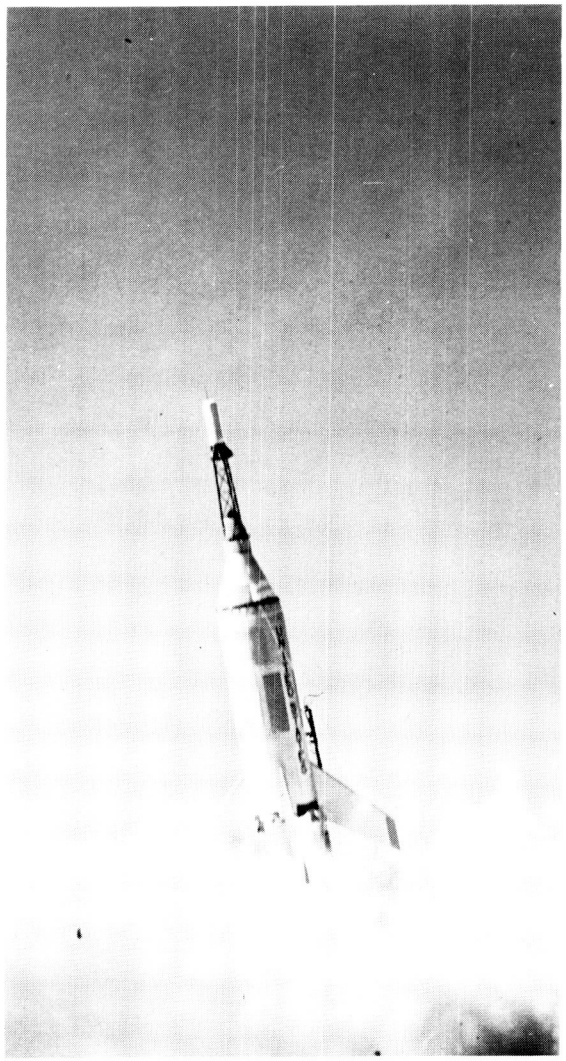
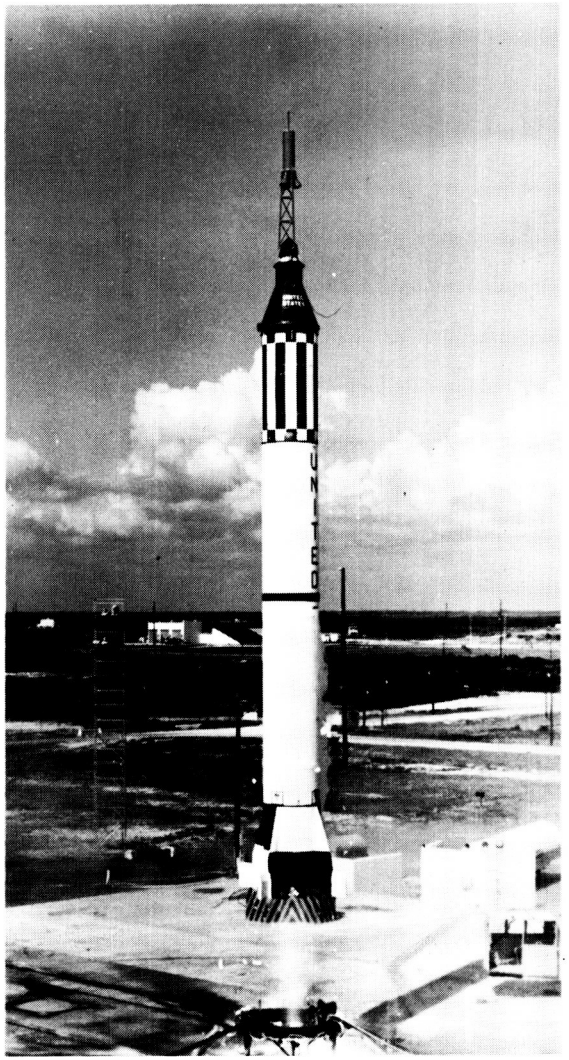


Figure 1

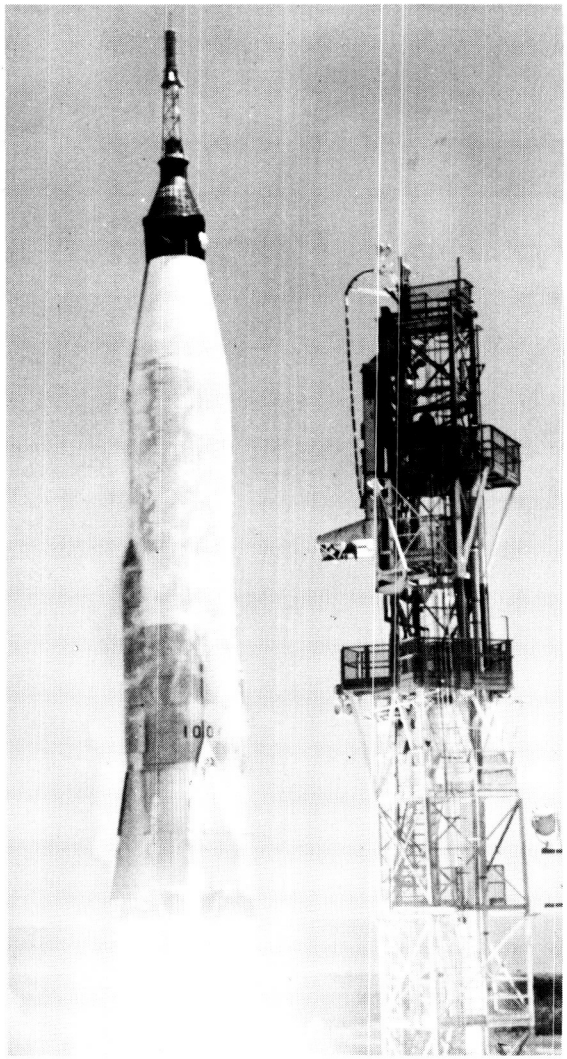
PROJECT MERCURY LAUNCH VEHICLES



LITTLE JOE

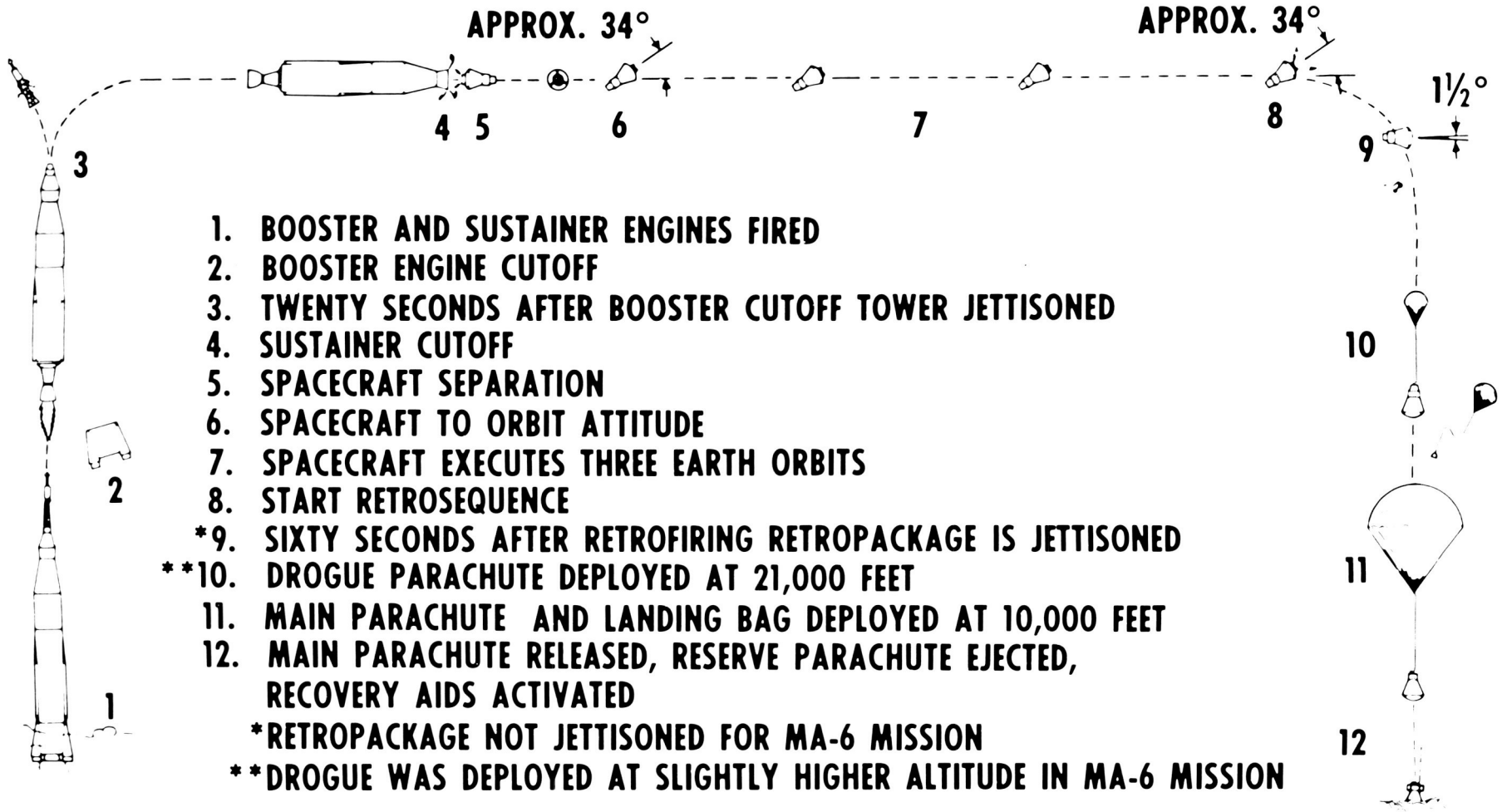


REDSTONE



ATLAS

Figure 2



1. BOOSTER AND SUSTAINER ENGINES FIRED
2. BOOSTER ENGINE CUTOFF
3. TWENTY SECONDS AFTER BOOSTER CUTOFF TOWER JETTISONED
4. SUSTAINER CUTOFF
5. SPACECRAFT SEPARATION
6. SPACECRAFT TO ORBIT ATTITUDE
7. SPACECRAFT EXECUTES THREE EARTH ORBITS
8. START RETROSEQUENCE

*9. SIXTY SECONDS AFTER RETROFIRING RETROPACKAGE IS JETTISONED

**10. DROGUE PARACHUTE DEPLOYED AT 21,000 FEET

11. MAIN PARACHUTE AND LANDING BAG DEPLOYED AT 10,000 FEET
12. MAIN PARACHUTE RELEASED, RESERVE PARACHUTE EJECTED, RECOVERY AIDS ACTIVATED

*RETROPACKAGE NOT JETTISONED FOR MA-6 MISSION

**DROGUE WAS DEPLOYED AT SLIGHTLY HIGHER ALTITUDE IN MA-6 MISSION

Figure 3

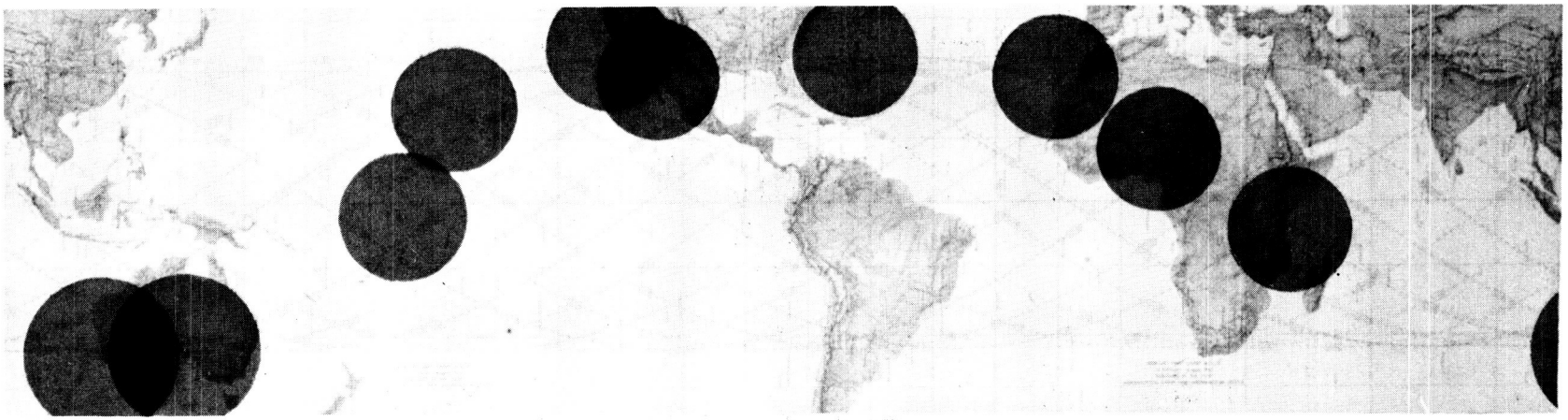


Figure 4

MERCURY CONTROL CENTER ORGANIZATION

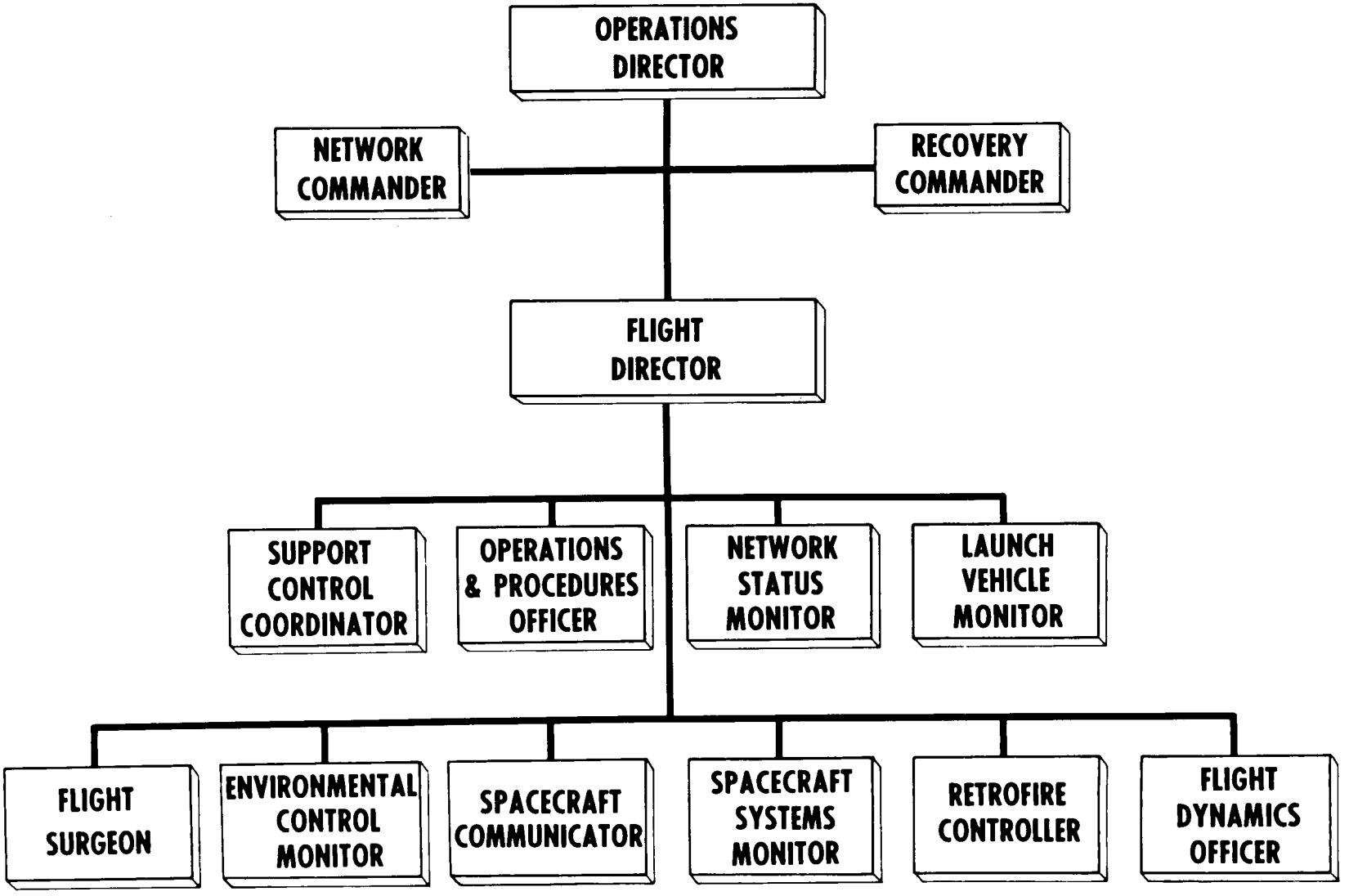


Figure 5

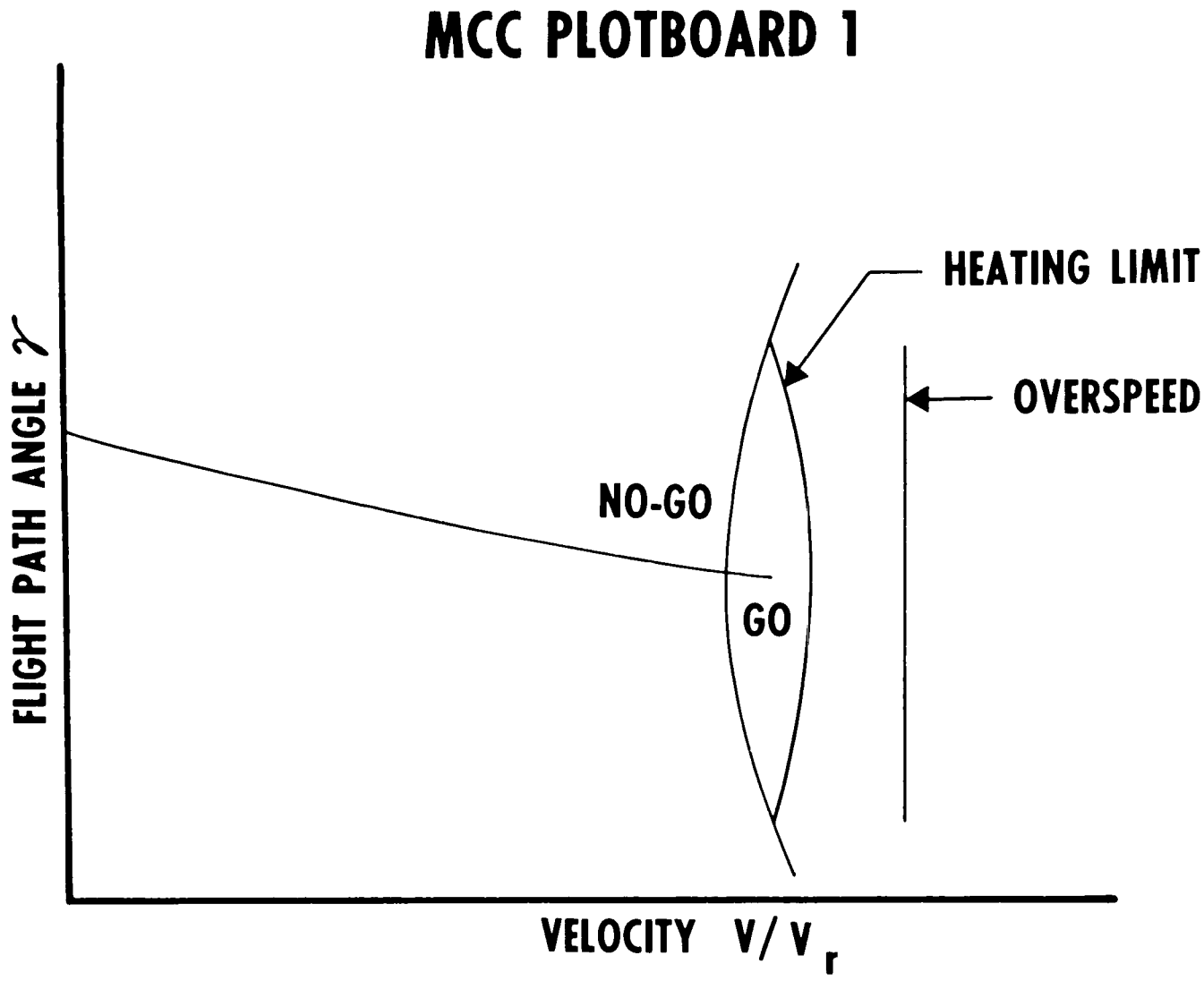

MCC PLOTBOARD 1
HEATING LIMIT
OVERSPEED
NO-GO
GO
FLIGHT PATH ANGLE γ
VELOCITY V/V r

Figure 6

MA-8 RECOVERY FORCES-PLANNED AREAS

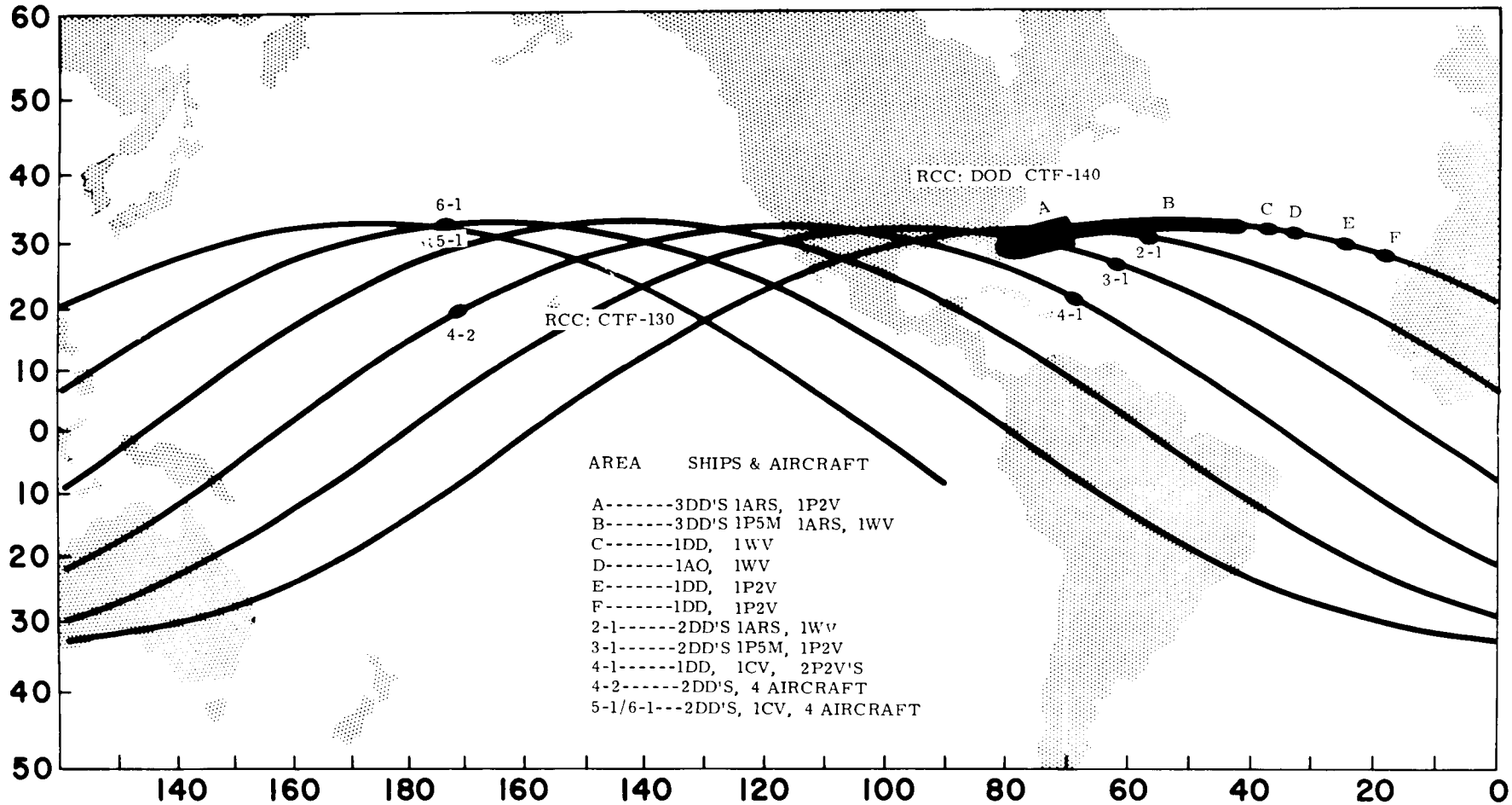


Figure 7

MERCURY 1 DAY MISSION

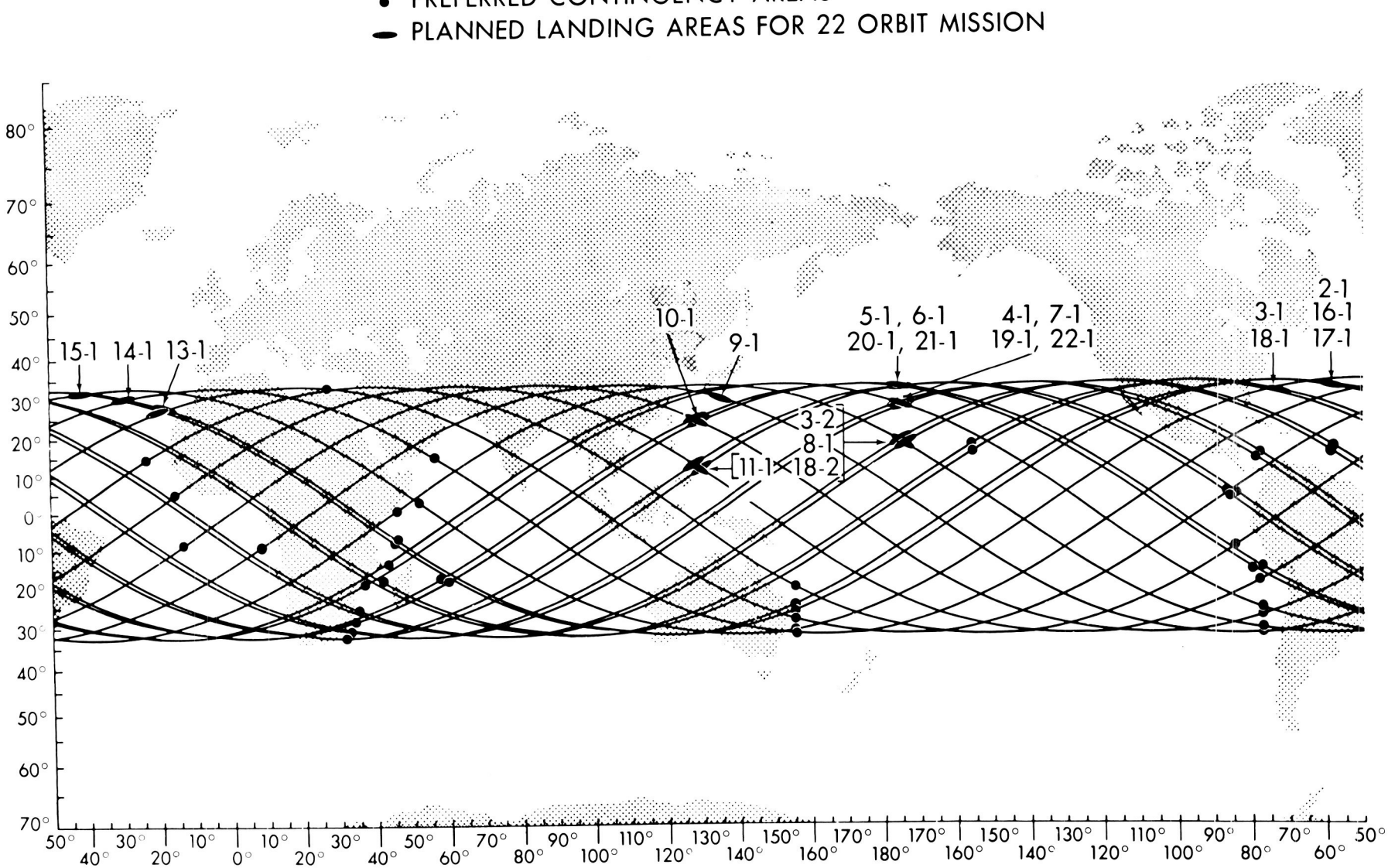


Figure 8

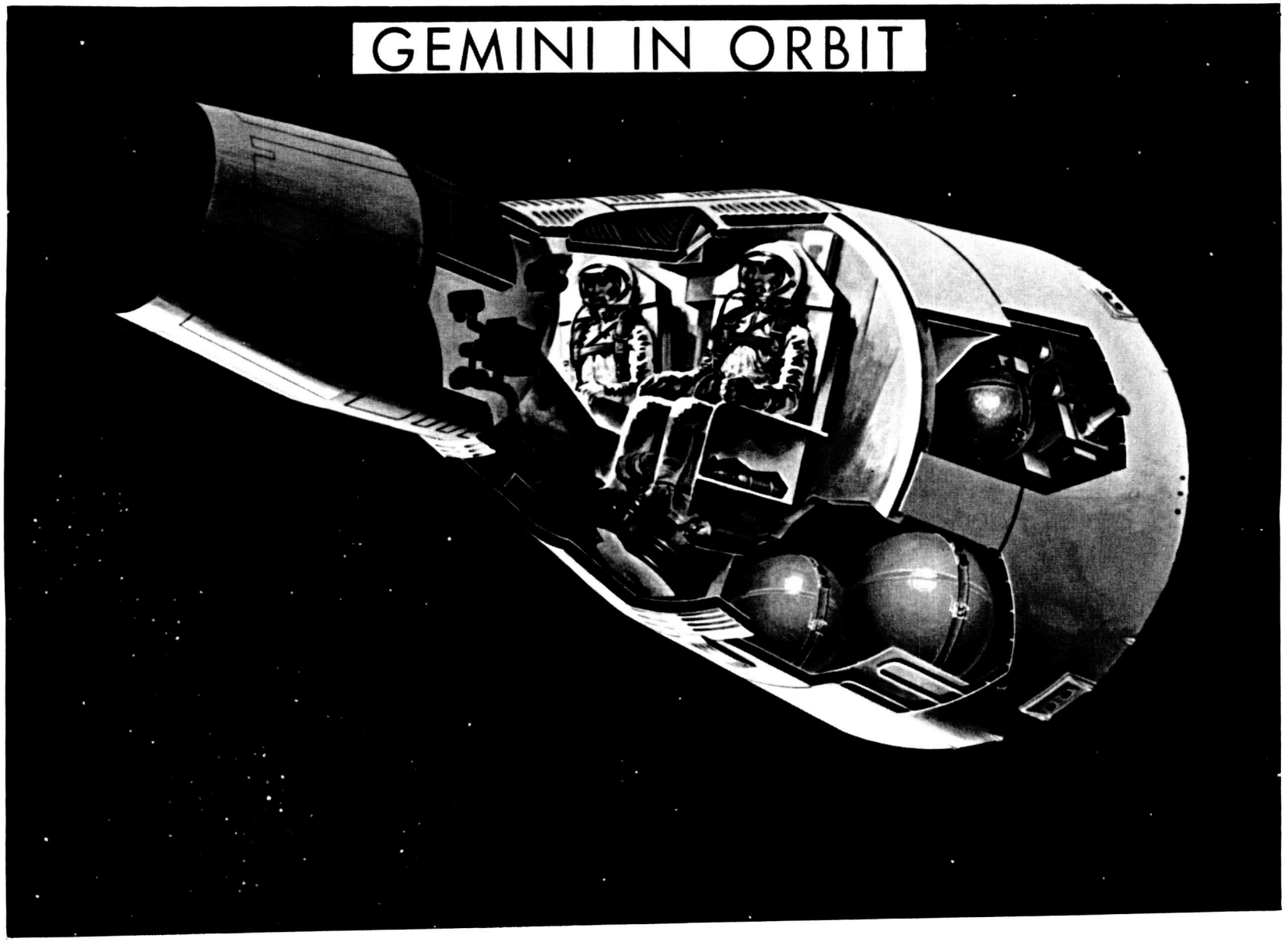
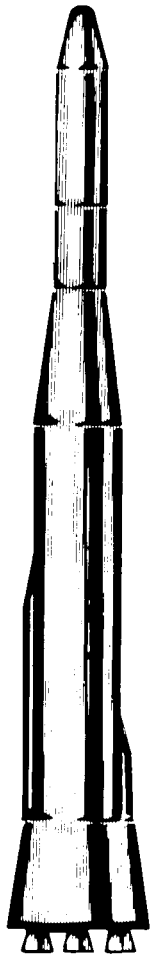


Figure 9

PROJECT GEMINI
LAUNCH VEHICLES

TITAN II



ATLAS-AGENA D

Figure 10

PROJECT GEMINI
FLIGHT MISSION

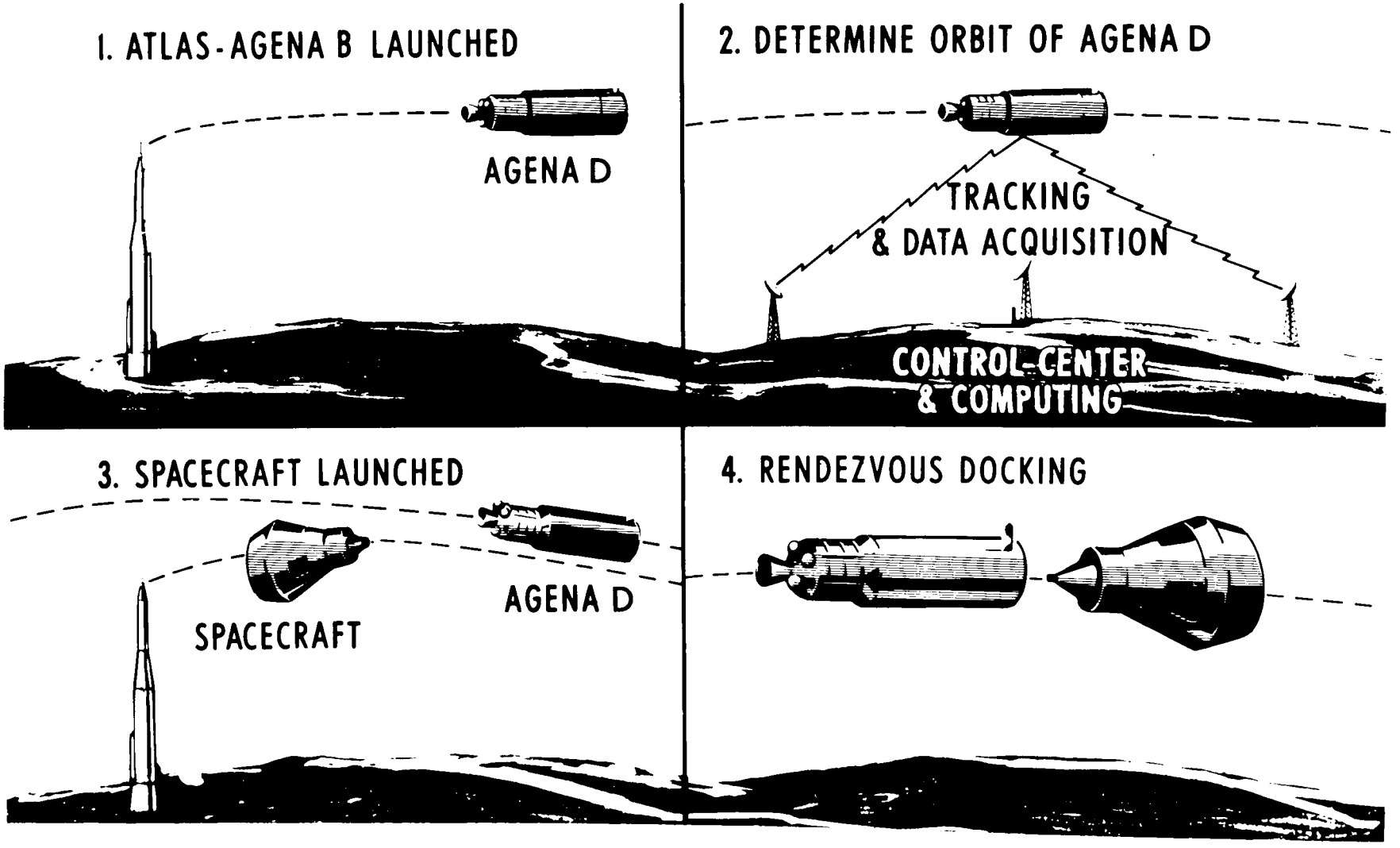


Figure 11

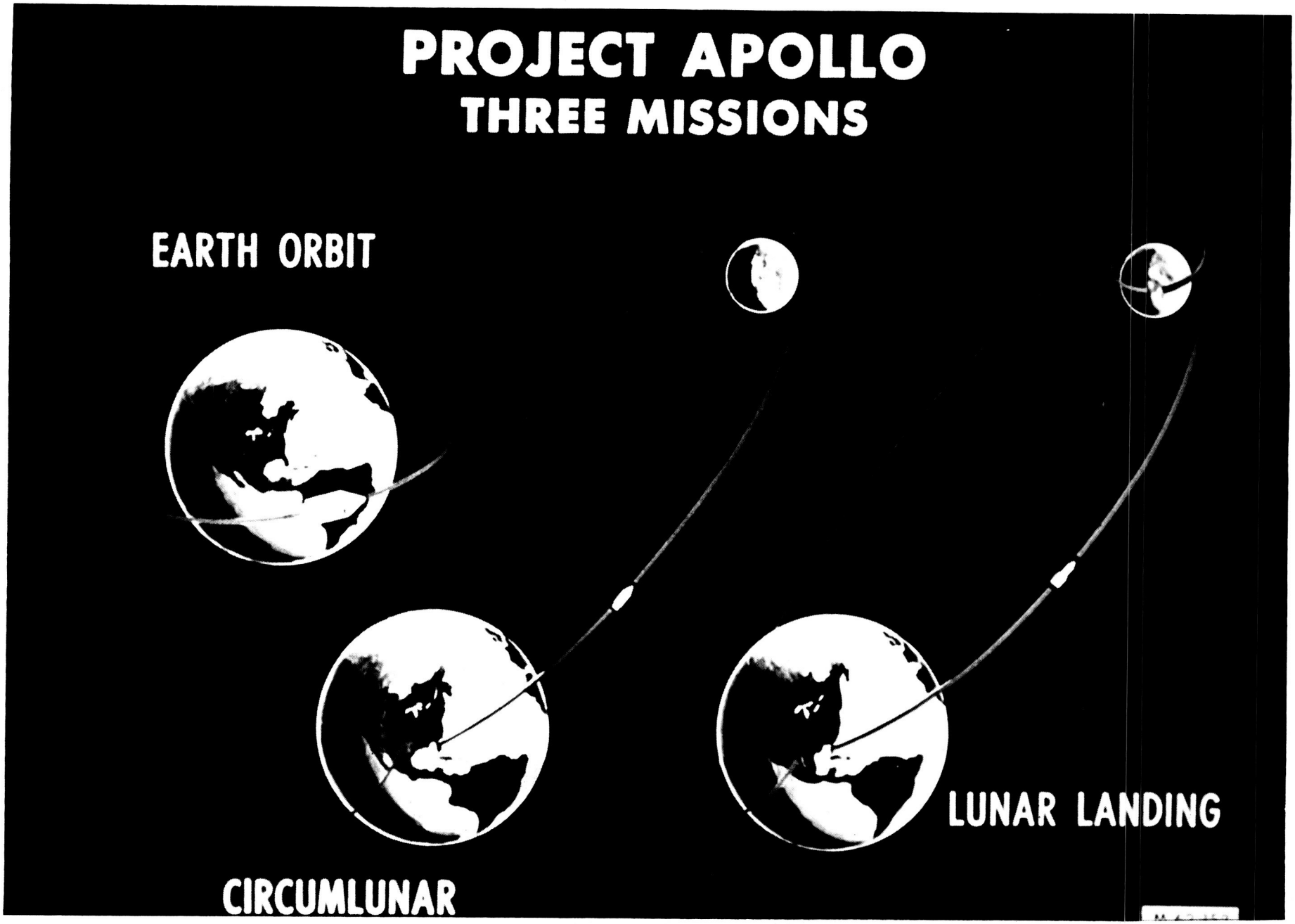

PROJECT APOLLO
THREE MISSIONS
EARTH ORBIT
CIRCUMLUNAR
LUNAR LANDING

Figure 12

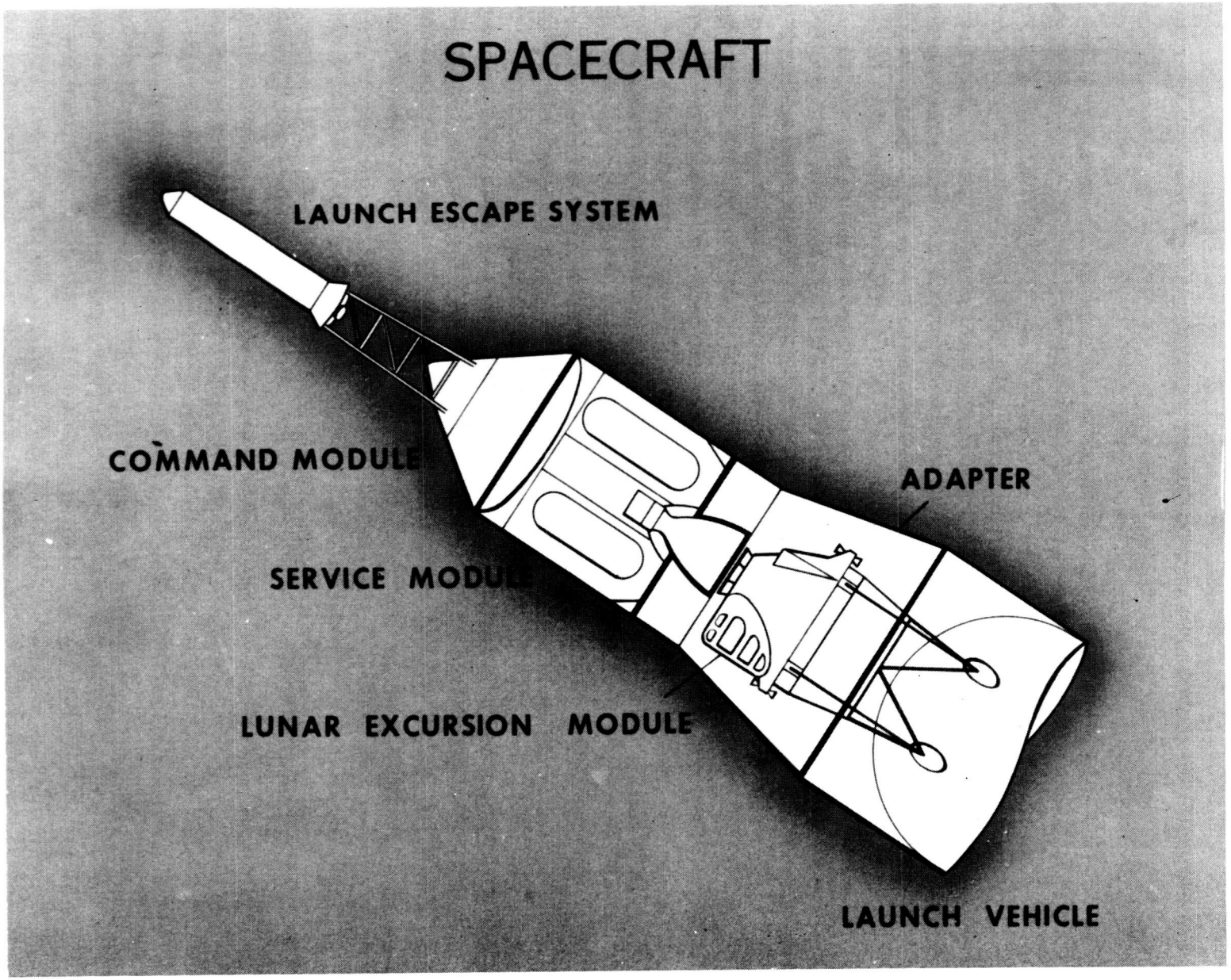

SPACECRAFT
LAUNCH ESCAPE SYSTEM
COMMAND MODULE
SERVICE MODULE
LUNAR EXCURSION MODULE
ADAPTER
LAUNCH VEHICLE

Figure 13

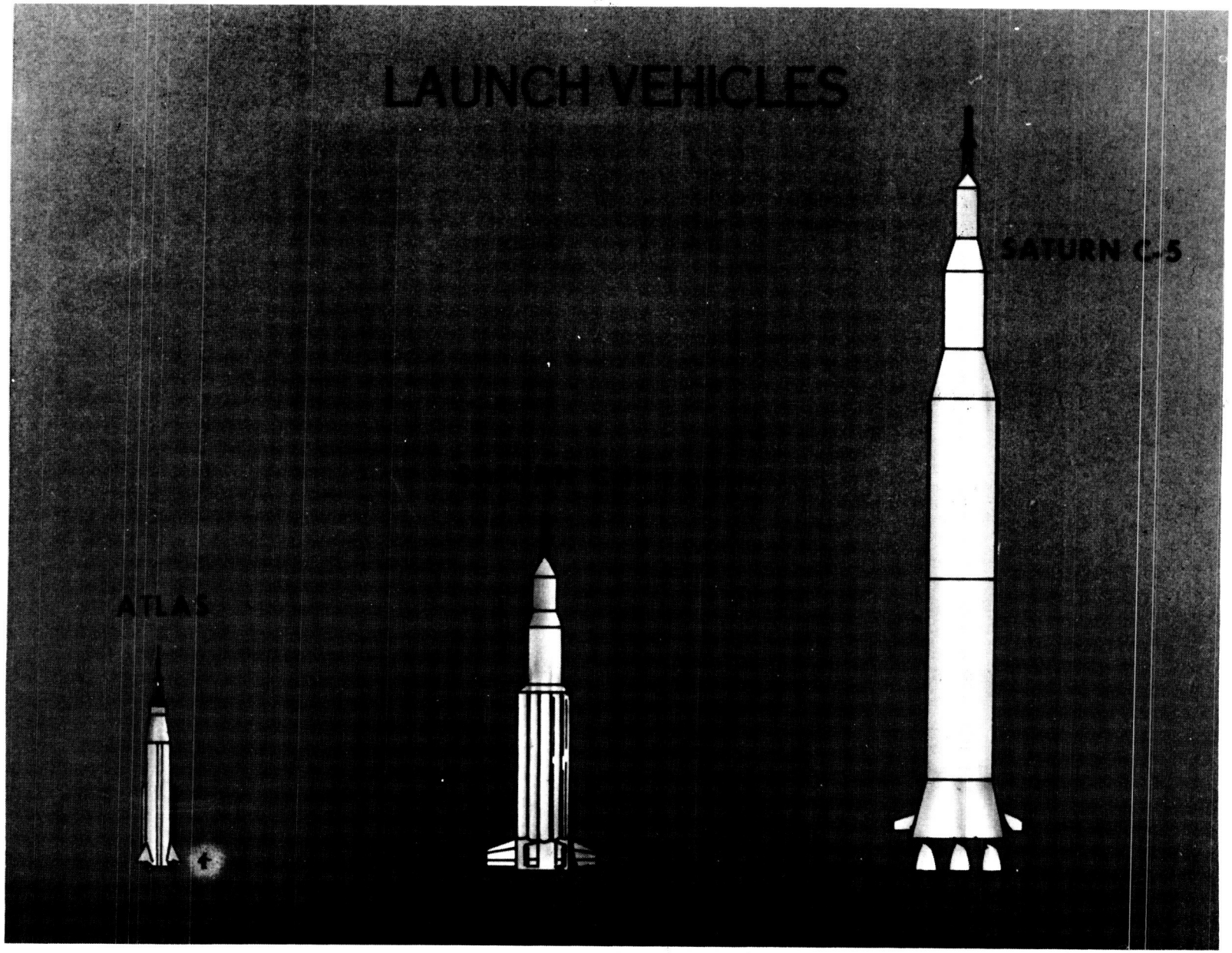


Figure 14

MISSION SEQUENCE CONFIGURATIONS

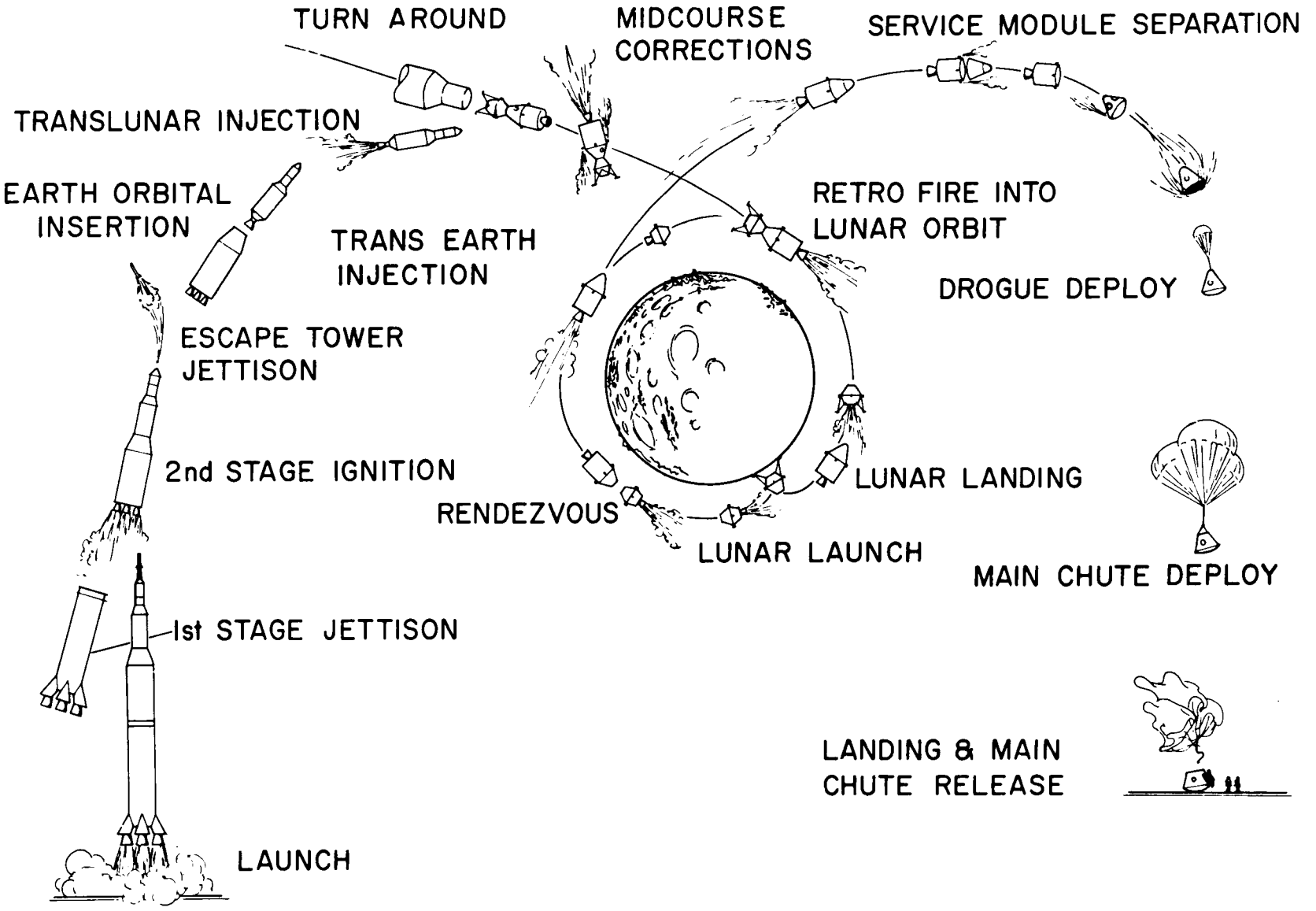


Figure 15